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(54) Title: SURVEY APPARATUS

(57) Abstract

A survey apparatus and method is provided which allows a user of the apparatus to view a target area on a screen using a camera. The image on the screen can be captured and a target within the screen selected to measure the distance or range to the target using a laser range finder.

1   "Survey Apparatus"

2

3   The present invention relates to a survey apparatus and

4   method.

5

6   Conventional survey equipment typically measures the

7   distance, bearing and inclination angle to a target

8   (such as a tree, electricity pylon or the like) or a

9   target area, with reference to the position of a user.

10   Such conventional equipment does not allow the user to

11   produce an image of the target which can be used to

12   measure heights and distances between objects within

13   the target area.

14

15   In addition, conventional sighting devices which are

16   used to select a target to be surveyed often result in

17   false surveys being made as the target is often not

18   correctly identified.

19

20   According to a first aspect of the present invention

21   there is provided a survey apparatus comprising a range

22   finder, a camera, a processor capable of processing

23   image and range signals, wherein the camera facilitates

24   aiming of the range finder.

25

2

1   According to a second aspect of the present invention

2   there is provided a method of measuring the range to a

3   target, the method comprising the steps of

4   providing a camera to view a target area;

5   providing a range finder;

6   using the camera to produce an image of the target

7   area;

8   selecting the target within the target area;

9   generating horizontal and vertical angles between

10 a reference point and the target; and

11   moving the range finder, if required, through the

12 generated horizontal and vertical angles to measure the

13 range to the target.

14

15 The camera is preferably a video camera, and more

16 preferably a digital video camera. The camera may

17 comprise a charge-coupled device (CCD) video camera.

18 Alternatively, the camera may comprise a digital image

19 camera. The apparatus typically includes a display

20 device to allow a user to view a target area using the

21 camera. The display device typically comprise a VGA

22 monitor. Alternatively, the display device may

23 comprise a VGA eyepiece monitor, such as a liquid-

24 crystal display (LCD) or flat panel display. This

25 offers the advantage that an image of the target may be

26 viewed by the user to ensure that the correct target

27 has been selected. Also, the survey apparatus may be

28 operated remotely using the camera to view the target

29 area.

30

31 The processor typically comprises a computer.

32

33 The range finder is typically a laser range finder.

34 Optionally, the laser range finder is bore-sighted with

35 the camera. This, in conjunction with the monitor used

36 to identify the target area, offers the advantage that

1   the user can be sure that the target area he has
2   selected will be captured by the camera, and that the
3   target area can be viewed remotely of the apparatus.
4   In addition, if the camera is bore-sighted with the
5   range finder, then any subsequent calculations made by
6   the image processor do not require an offset between
7   the camera and the range finder to be considered.
8
9   The apparatus typically calculates the range to
10   specified points and incorporates such distance
11   measurements into the image displayed on a screen.
12
13   The apparatus preferably includes a pan and tilt unit
14   for panning and tilting of the range finder and/or
15   camera. The pan and tilt unit typically comprises a
16   first motor for panning of the range finder and/or
17   camera, and a second motor for tilting of the range
18   finder and/or camera. The pan and tilt unit typically
19   includes first and second digital encoders for
20   measuring the angles of pan and tilt. The first and
21   second motors are typically controlled by the
22   processor. The outputs of the first and second
23   encoders is typically fed to the processor. This
24   provides a feedback loop wherein the motors are
25   operated to pan and tilt the range finder and/or camera
26   through the generated horizontal and vertical angles.
27   The encoders may then be used to check the angles to
28   ensure that the range finder and/or camera were panned
29   and tilted through the correct angles.
30
31   The image is preferably digitised, wherein the image
32   comprises a plurality of pixels. The reference point
33   is typically a pixel within the target area, and may be
34   a centre point of the target area or one of the
35   corners. The target is typically selected by selecting
36   a pixel within the target, using, for example, a mouse

4

1   pointer. This produces x and y coordinates for the
2   target pixel.
3
4   Optionally, the survey apparatus includes a compass and
5   an inclinometer and/or gyroscope. The compass is
6   typically a digital fluxgate compass. These allow the
7   bearing and angle of inclination to the target to be
8   measured. The signals from the compass, inclinometer
9   and/or gyroscope are preferably digitised to provide
10 data to the processor. The bearing and/or angle of
11 inclination to the target can be displayed on the
12 screen.
13
14 Optionally, the survey apparatus further includes a
15 position fixing system for identifying the geographical
16 position of the apparatus. The position fixing system
17 is preferably a Global Positioning System (GPS) which
18 typically includes a Differential Global Positioning
19 System (DGPS). This provides the advantage that the
20 approximate position of the apparatus can be recorded
21 (and thus the position of the target using the
22 measurements from the range finder and compass, where
23 used). The GPS/DGPS typically facilitates the time of
24 the survey to be recorded. The signal from the GPS is
25 typically digitised to provide data to the processor.
26
27 The survey apparatus is typically mounted on a mounting
28 device. The mounting device typically comprises a
29 tripod stand. The apparatus can optionally be mounted
30 on an elevating platform, telescopic elevating tube,
31 telescopic arm, robotic arm or the like. This provides
32 the apparatus with a larger viewing area. The
33 elevating platform or the like is typically capable of
34 360° rotation. This provides a complete viewing range.
35
36 The apparatus allows data gathering from within a

1 vehicle to construct a digital terrain model of the
2 terrain surrounding the vehicle.
3
4 The method typically comprises any one, some or all of
5 the further steps of
6   obtaining a focal length of the camera;
7   obtaining a field of view of the camera;
8   calculating the principal distance of the camera;
9   obtaining the horizontal offset and vertical
10 offset between an axis of the camera and an axis of the
11 laser;
12   calculating the horizontal and vertical offsets in
13 terms of pixels;
14   calculating the difference between the horizontal
15 and vertical offsets in terms of pixel and the x and y
16 coordinates of the target pixel; and
17   calculating the horizontal and vertical angles.
18
19 Optionally, the method typically includes one, some or
20 all of the further steps of
21   instructing the pan and tilt unit to pan and tilt
22 the range finder and/or camera through the vertical and
23 horizontal angles;
24   measuring the horizontal and vertical angles using
25 the encoders;
26   verifying that the angles through which the range
27 finder and/or camera are moved is correct;
28   obtaining horizontal and/or vertical correction
29 angles by subtracting the measured horizontal and
30 vertical angles from the calculated horizontal and
31 vertical angles;
32   adjusting the pan and tilt of the range finder
33 and/or camera if necessary; and
34   firing the range finder to obtain the range to the
35 target.
36

6

1   Embodiments of the present invention shall now be
2   described, with reference to the accompanying drawings,
3   in which:-
4   Fig. 1 is a schematic representation of a image
5   capture and laser transmitter and receiver unit in
6   accordance with, and for use with, the present
7   invention;
8   Fig. 2 shows schematically a first embodiment of
9   survey apparatus;
10   Fig. 3 shows an exploded view of the survey
11   apparatus of Fig. 2 in more detail;
12   Fig. 4 shows a simplified schematic illustration
13   of a digital encoder;
14   Fig. 5 schematically shows the survey apparatus of
15   Figs 2 and 3 in use;
16   Fig. 6 is a schematic representation of the
17   display produced on a computer screen of a freeze
18   frame image produced by a digital camera;
19   Fig. 7 is a simplified schematic diagram of inside
20   a digital camera;
21   Fig. 8 is a simplified diagram illustrating how a
22   principal distance (PD) may be calculated;
23   Fig. 9 is a simplified diagram illustrating the
24   offset between the laser and the camera in use;
25   Fig. 10 is a schematic representation illustrating
26   a horizontal offset H_{offset} outwith the camera;
27   Fig. 11 is a schematic representation illustrating
28   a horizontal distance l_x in terms of pixels,
29   corresponding to H_{offset}, within the camera;
30   Fig. 12 is a simplified diagram of a freeze frame
31   image showing an object;
32   Fig. 13 is a schematic representation illustrating
33   the relationship between a horizontal distance d_x,
34   a principal distance PD and an angle θ;
35   Fig. 14 is a schematic representation of a screen
36   image of a target overlayed with range, bearing

1   and inclination information;

2   Fig. 15a is a schematic representation of a

3   vehicle provided with an elevating arm and survey

4   apparatus showing the position of the apparatus

5   when the vehicle is moving;

6   Fig. 15b is a schematic representation of the

7   vehicle of Fig. 15a with the apparatus deployed on

8   the arm;

9   Fig. 15c is a schematic representation of the

10 vehicle of Figs 15a and 15b on a slope with the

11 apparatus deployed on the arm;

12 Figs 16a and 16b are respective rear and side

13 views of the survey apparatus deployed on the arm;

14 Fig. 17 is an exemplary screen shot of an area

15 which has been surveyed using the survey

16 apparatus;

17 Figs 18a and 18b are respective side and plan

18 elevations of the vehicle of Figs 15a to 15c

19 illustrating the survey apparatus being used to

20 profile the ground in front of the vehicle;

21 Figs 19a and 19b are side and plan views of the

22 profile of the ground in front of the vehicle

23 which is displayed for a user of the apparatus;

24 Fig. 20 illustrates a head-up display used by the

25 driver of the vehicle, the display being generated

26 by the survey apparatus;

27 Fig. 21 illustrates calculating the height

28 difference between two points A and B using the

29 survey apparatus;

30 Fig. 22 illustrates calculating the height and

31 distance between two points A and B using the

32 survey apparatus; and

33 Fig. 23 illustrates using the survey apparatus to

34 profile a surface.

35

36 Referring to the drawings, Fig. 1 shows a schematic

1   representation of an image capture and laser

2   transmitter and receiver unit 10 for use with the

3   present invention. Unit 10 includes a laser 12 (which

4   forms part of a laser range finder) which generates a

5   beam of laser light 14. The laser 12 is typically an

6   invisible, eyesafe, gallium arsenide (GaAs) diode laser

7   which emits a beam typically in the infra-red (IR)

8   spectrum. The laser 12 is typically externally

9   triggered and is designed to measure up to 1000 metres

10 or more to reflective and non-reflective targets. Any

11 particular type of laser 12 may be used and the present

12 invention is not limited to the particular embodiment

13 shown.

14

15 The beam 14 is reflected by a part-silvered prism 16 in

16 a first direction substantially perpendicular to the

17 direction of the initial beam 14, thereby creating a

18 transmit beam 18. The transmit beam 18 enters a series

19 of transmitter optics 20 which collimates the transmit

20 beam 18 into a target beam 22. The target beam 22 is

21 reflected by a target (schematically shown in Fig. 1 at

22 24) and is returned as a reflected beam 26. The

23 reflected beam 26 is collected by a series of receiver

24 optics 28 and directs it to a laser light detector 30.

25 The axes of the transmit and receiver optics 20, 28 are

26 calibrated to be coincident at infinity.

27

28 Signals from the detector 30 are sent to a processor

29 (not shown) which calculates the distance from the

30 apparatus 10 to the target 24 using a time-of-flight

31 principle. Thus, by dividing the time taken for the

32 light to reach the target 24 and be reflected back to

33 the detector 30 by two, the distance to the target 24

34 may be calculated.

35

36 Bore-sighted with the laser 12 (using the part-silvered

1   prism 16) is a digital video camera 32. The camera 32

2   is preferably a complementary metal-oxide silicon

3   (CMOS) camera which is formed on a silicon chip. The

4   chip generally includes all the necessary drive

5   circuitry for the camera 32. It should be noted that

6   the camera need not be bore-sighted with the laser. In

7   this case, the transmit laser beam 22 will be offset in

8   the x and/or y directions from the centre of the

9   picture taken by the camera 32. The offsets can be

10   calculated and the survey apparatus calibrated (using

11   software) to take into account the offsets, as will be

12   described.

13

14   The transmit optics 20 serve a dual purpose by also

15   acting as a lens for the camera 32. Thus, light which

16   enters the transmit optics 20 is collimated and

17   directed to the camera 32 (shown schematically at 34)

18   thereby producing an image of the target 24 at the

19   camera 32. The image which the camera 32 receives is

20   digitised and sent to a processor (not shown). It

21   should be noted that a separate lens may be used for

22   the camera 32 if required.

23

24   Referring now to Figs 2 and 3, Fig. 2 shows

25   schematically a first embodiment of survey apparatus

26   100 mounted for movement in x and y directions, and

27   Fig. 3 shows an exploded view of the survey apparatus

28   100 of Fig. 2 in more detail.

29

30   Referring firstly to Fig. 2, the image capture and

31   laser transmitter and receiver unit 10 (Fig. 1) is

32   typically mounted within a casing 50. The casing 50 is

33   typically mounted to a U-shaped yoke 52, yoke 52 being

34   coupled to a vertical shaft 54. Shaft 54 is rotatably

35   mounted to facilitate rotational movement (indicated by

36   arrow 56 in Fig. 2) of the casing 50 in a horizontal

1   plane (indicated by axis 58) which is the x-direction.

2   The rotational movement of the shaft 54 (and thus the

3   yoke 52 and casing 50) is controlled by a motor 60

4   coupled to the shaft 54, typically via a gearbox (not

5   shown in Fig. 2). The operation of the motor 60 is

6   controlled by the computer.

7

8   The angle of rotation of the casing 50 in the

9   horizontal plane (ie the x-direction) is measured

10   accurately by a first digital encoder 62, attached to

11   the shaft 54 in a known manner, which measures the

12   angular displacement of the casing 50 (and thus the

13   transmit laser beam 22) in the x-direction.

14

15   Similarly, the yoke 52 allows the casing 50 (and thus

16   the transmit laser beam 22) to be displaced in the y-

17   direction as indicated by arrow 64. The casing 50 is

18   mounted to the yoke 52 via a horizontal shaft 66.

19   Shaft 66 is rotatably mounted to facilitate rotational

20   movement (indicated by arrow 64 in Fig. 2) of the

21   casing 50 in a vertical plane (indicated by axis 68)

22   which is the y-direction. The rotational movement of

23   the shaft 66 (and thus the yoke 52 and casing 50) is

24   controlled by a motor 68 coupled to the shaft 56,

25   typically via a gearbox (not shown in Fig. 2). The

26   operation of the motor 66 is controlled by the

27   computer.

28

29   The angle of rotation of the casing 50 in the vertical

30   plane (ie the y-direction) is measured accurately by a

31   second digital encoder 70, attached to shaft 66 in a

32   known manner, which measures the angular displacement

33   of the casing 50 (and thus the transmit laser beam 22)

34   in the y-direction. Thus, the motors 60, 68 provide

35   for panning and tilting of the casing 50.

36

1   The output of the first and second encoders 62, 70 is
2   electrically coupled to the computer to provide a
3   feedback loop. The feedback loop is required because
4   the motors 60, 68 are typically coupled to the shafts
5   54, 66 via respective gearboxes and are thus not in
6   direct contact with the shafts 54, 66. This makes the
7   movement of the casing 50 which is effected by
8   operation of the motors 60, 68 less accurate. However,
9   as the encoders 62, 70 are coupled directly to their
10   respective shafts 54, 66 then the panning and tilting
11   of the casing in the x- and y-directions can be
12   measured more accurately, as will be described.
13
14   The embodiment of the image capture and laser
15   transmitter and receiver unit 10 shown in Fig. 2 is
16   slightly different from that illustrated in Fig. 1.
17   The camera within unit 10 is not bore-sighted with the
18   laser, and thus casing 50 is provided with a camera
19   lens 72, a laser transmitter lens 74 and a laser
20   receiver lens 76. It should be noted that the laser
21   transmitter lens 74 and the camera lens 72 may be
22   integrated into a single lens as illustrated in Fig. 1.
23   Ideally, the camera lens 72, laser transmitter lens 74
24   and laser receiver lens 76 would be co-axial. This
25   could be achieved in practice by mechanically adjusting
26   the lenses 72, 74, 76 to make them co-axial. However,
27   this is a time consuming process and the offsets
28   between the lenses can be calculated and the survey
29   apparatus can be calibrated to take these offsets into
30   account, as will be described. This calibration is
31   generally simpler and quicker than mechanically
32   aligning the lenses 72, 74, 76.
33
34   Referring to Fig. 3, there is shown in more detail the
35   apparatus of Fig. 2. It should be noted that the
36   casing 50 which houses the image capture and laser

12

1   transmitter and receiver unit 10 is not provided with a
2   separate camera lens (as in Fig. 2). It should also be
3   noted that the casing 50 in Fig. 3 is mounted to
4   facilitate rotational movement in the x-direction, but
5   can be manually tilted in the y-direction.
6
7   As can be seen more clearly in Fig. 3, the casing 50 is
8   mounted to the U-shaped yoke 52. The yoke 52 is
9   coupled to the shaft 54 using any conventional means
10 such as screws 80. The shaft 54 is driven by the
11 stepper motor 60 via a worm/wheel drive gearbox 82.
12 The digital encoder 62 is provided underneath a plate
13 84 through which the shaft 54 passes and to which the
14 gearbox/motor assembly is attached. Plate 84 also
15 includes a rotary gear assembly 86 which is driven by
16 the motor 60 via the worm gearbox 82 to facilitate
17 rotational movement of the shaft 54.
18
19 The motor, gearbox and shaft assembly is mounted within
20 an aluminium casing 86, the casing 86 also having a
21 rack 88 mounted therein. The rack 88 contains the
22 necessary electronic circuitry for driving and
23 controlling the operation of the survey apparatus, and
24 includes a stepper motor driver board 90, a laser
25 control board 92 and an interface board 94.
26
27 The first and second digital encoders 62, 70 may be of
28 any conventional type, such as Moir Fringe, barcode or
29 mask. Moir fringe type encoders are typically used as
30 they are more accurate. Fig. 4 shows a simplified
31 schematic illustration of a digital encoder, generally
32 designated 110. Encoder 110 typically comprises a
33 casing 112 in which a disc 114 is rotatably mounted.
34 The disc 114 is provided with a pattern and is
35 typically at least partially translucent. The type of
36 pattern defined on the disc 114 determines the type of

1   encoder.

2

3   A light emitting diode (LED) 116 is suspended above the

4   disc 114 and emits a light beam (typically collimated

5   by a lens (not shown) which shines through the disc

6   114. The light emitted by the LED 116 is detected by a

7   detector, typically a cell array 118. As the disc 114

8   rotates (in conjunction with the shaft to which it is

9   coupled) a number of electrical outputs are generated

10   per revolution of the disc 114 by the cell array 118

11   which detects the light passing through the disc 114

12   from the LED 116. These types of encoders usually have

13   two output channels (only one shown in Fig. 4) and the

14   phase relationship between the two signals can be used

15   to determine the direction of rotation of the disc 114.

16

17   The encoder 110 produces a pulse output per unit of

18   revolution. Thus, as the disc 114 rotates, the pattern

19   on the disc 114 causes electrical pulses to be

20   generated by the cell array 118 in response to the

21   pattern on the disc 114. These pulses can be counted

22   and, given that one pulse is proportional to a certain

23   degree of rotation, the angular rotation of the disc

24   114 and thus the shaft 54 can be calculated.

25

26   Fig. 5 shows the survey apparatus 100 (schematically

27   represented in Fig. 5 but shown more clearly in Figs 2

28   and 3) in use. The apparatus 100 is controlled and

29   operated using software installed on the computer

30   (shown schematically at 120) via a cable 122, telemetry

31   system or other remote or hardwired control. An image

32   of the target is displayed on the computer screen using

33   the camera 32 (Fig. 1) and is schematically shown as

34   image 124 in Fig. 5. When the image 124 of the target

35   area of interest is viewed on the screen, the user of

36   the apparatus 100 instructs the camera 32 (included as

14

1   part of the apparatus 100) to take a freeze frame image

2   of the target area. The freeze frame image 124 is a

3   digital image made up of a plurality of pixels and Fig.

4   6 is a schematic representation of the display produced

5   on the computer screen of the freeze frame image 124.

6   The image 124 is typically divided into an array of

7   pixels, with the image containing, for example, 200 by

8   200 pixels in the array.

9

10   Each pixel within the array has an x and y coordinate

11   associated with it using, for example, the centre C of

12   the picture as a reference point. Thus, each pixel

13   within the digital image can be individually addressed

14   using these x and y co-ordinates.

15

16   The individual addresses for each pixel allow the user

17   to select a particular object (for example a tree 126)

18   within the digital image 124. The tree 126 can be

19   selected using a mouse pointer for example, where the

20   mouse pointer is moved around the pixels of the digital

21   image by movement of a conventional mouse provided with

22   the computer in a known manner. The x and y

23   coordinates of each pixel may be displayed on the

24   screen ad the mouse pointer is moved around the image.

25   Clicking the mouse button with the pointer on the tree

26   126 selects a particular pixel 128 within the array

27   which is identified by its x and y coordinates.

28

29   The computer is then used to calculate the horizontal

30   angle H_A and the vertical angle V_A (Fig. 6). The

31   horizontal angle H_A and the vertical angle V_A are the

32   relative angles between the centre point C of the image

33   and the pixel 128, as schematically shown in Fig. 6.

34

35   The methodology for calculating the horizontal angle H_A

36   and the vertical angle V_A from the pixel x, y

1 coordinates is as follows. Fig. 7 is a simplified

2 schematic diagram of inside the camera 32 which shows

3 the camera lens 72 and a charge-coupled device (CCD)

4 array 130.   The camera 32 is typically a zoom camera

5 which therefore has a number of focal lengths which

6 vary as the lens 72 is moved towards and away from the

7 CCD array 130.

8

9 Referring to Fig. 7, the angles of horizontal and

10 vertical views, or the field of view in the horizontal

11 and vertical direction θ_H, θ_V (θ_V not shown in Fig. 7)

12 can be calibrated and calculated at different focal

13 lengths of the camera 32. For simplicity, it is

14 assumed that the CCD array 130 is square, and thus the

15 field of view in the horizontal and vertical directions

16 θ_H, θ_V will be the same, and thus only the field of view

17 in the horizontal direction θ_H will be considered. The

18 methodology described below considers one zoom position

19 only.

20

21 Having calculated (or otherwise obtained) the field of

22 view in the horizontal direction θ_H then the principal

23 distance PD (in pixels) can be calculated. The

24 principal distance PD is defined as the distance from

25 the plane of the lens 72 to the image plane (ie the

26 plane of the CCD array 130).

27

28 Referring to Fig. 8, if the image width on the CCD

29 array is defined as H_R, then using basic trigonometry

30 $\tan(\theta_H/2) = H_R/(2PD)$. Thus,

31

32          $$PD = H_R/2(\tan(\theta_H/2))$$

33

34 If the distance between each pixel in the image 124 in

35 a certain unit (ie millimetres) is known, then the

36 principal distance PD can be converted into a distance

16

1   in pixels.   For example, if the field of view in the
2   horizontal and vertical angles θ_H, θ_V is, for example
3   10°, and the image contains 200 by 200 pixels, then
4   moving one twentieth of a degree in the x or y
5   direction is the equivalent of moving one pixel in the
6   x or y direction.
7
8   When initially using the apparatus 100, the camera 32
9   is used to take a calibration freeze frame image and
10   the laser 12 is activated to return the range R to the
11   centre point C of the image. However, the laser axis
12   is typically offset from the camera axis. The
13   horizontal and vertical offsets between the laser axis
14   and the camera axis when the freeze frame image is
15   taken are defined as H_{offset} and V_{offset} and are known.
16   Knowing the range R and the horizontal and vertical
17   offsets H_{offset}, V_{offset} allows the offset horizontal and
18   vertical distances l_x and l_y in terms of pixels to be
19   calculated. Referring to Fig. 9, the centre point C of
20   the image 124 taken by the camera 32 and the laser spot
21   132 where the transmit laser beam 22 hits the target
22   area is typically offset by the horizontal and vertical
23   distances l_x and l_y.
24
25   Fig. 10 is a schematic representation illustrating the
26   horizontal offset H_{offset} outwith the camera 32, and Fig.
27   11 is a schematic representation illustrating the
28   horizontal distance l_x in terms of pixels, corresponding
29   to H_{offset}, within the camera 32.   Referring to Figs 10
30   and 11 and using basic trigonometry,
31
32                         $$\tan \theta = H_{offset}/R$$
33   and,
34                         $$l_x = PD(\tan \theta)$$
35   Thus,
36                         $$l_x = PD(H_{offset}/R)$$

1 and it follows that

2 $$l_y = PD(V_{offset}/R)$$

3

4

5

6 If the range to a certain object within the target area

7 (such as the tree 126 in Fig. 6) is required, then the

8 computer must calculate the horizontal and vertical

9 angles H_A, H_V through which the casing 50 and thus the

10 laser beam 22 must be moved in order to target the

11 object.

12

13 The user selects the particular pixel (relating to the

14 object of interest) within the image using a mouse

15 pointer. In Fig. 12, the selected object is

16 represented by pixel A which has coordinates (x, y),

17 and the laser spot 132 has coordinates (l_x, l_y)

18 calculated using the previous method. The coordinates

19 (x, y) of point A are already known using the

20 coordinates of the pixel array of the image.

21

22 If the horizontal distance between pixel A and the

23 laser spot 132 is defined as d_x, and similarly the

24 vertical distance between pixel A and the laser spot

25 132 is defined as d_y, then

26

27 $$d_x = x - l_x$$

28 and

29 $$d_y = y - l_y,$$

30

31 and it follows that the horizontal and vertical angles

32 H_A, V_A can be calculated as

33

34 $$H_A = \text{inverse tan } (d_x/PD)$$

35

36 and

18

1          $V_A = $ inverse tan (d_y/PD).

2

3   Referring back to Fig. 2, having calculated the

4   horizontal and vertical angles H_A, V_A through which the

5   casing 50 must be rotated to measure the range to the

6   object A, the computer 120 instructs the motor 60 to

7   pan through an angle of H_A and simultaneously instructs

8   the motor 68 to tilt through an angle of V_A. Thus, the

9   transmit laser beam 22 is directed at the object A

10   selected by the user to determine the range to it.

11

12   However, the motors 60, 68 are not directly coupled to

13   the shafts 54, 66 (but via respective gearboxes) and

14   thus can have errors which results in the laser beam 22

15   not being directed precisely at the object A. However,

16   the encoders 62, 70 can be used to measure more

17   precisely the angles H_A and V_A through which the casing

18   50 was panned and tilted. If there is a difference

19   between the measured angles H_A and V_A and the angles

20   which were calculated as above, the computer can

21   correct for this and can pan the casing 50 through an

22   angle H_{AC} which is the difference between the calculated

23   angle H_A and the measured angle H_A, and similarly tilt

24   the casing 50 through an angle V_{AC} which is the

25   difference between the calculated angle V_A and the

26   measured angle V_A. The process can then be repeated by

27   using the encoders 62, 70 to check that the casing 50

28   has been panned and tilted through the angles H_{AC} and

29   V_{AC}. If there is a difference again, then the process

30   can be repeated to further correct for the errors

31   introduced. This iteration process can be continued

32   until the output from the decoders 62, 70 corresponds

33   to the correct angles H_A and V_A. The laser 12 is then

34   fired to give the range to the object A.

35

36   The user may then select another object within the

19

1   image 124 which is of interest and use the above
2   process to determine the range to that particular
3   object. It should be noted however, that the process
4   to determine the distances l_x and l_y need not be
5   repeated as these distances will be constants.
6
7   The apparatus 100 can optionally include a Global
8   Positioning System (GPS) (not shown). The GPS is a
9   satellite navigation system which provides a three-
10 dimensional position of the GPS receiver (in this case
11 mounted as part of the survey apparatus 100) and thus
12 the position of the survey apparatus 100. The GPS is
13 used to calculate the position of the apparatus 100
14 anywhere in the world to within approximately ± 25
15 metres. The GPS calculates the position of the
16 apparatus 100 locally using radio/satellite broadcasts
17 which send differential correction signals to ± 1
18 metre. The GPS can also be used to record the time of
19 all measured data to 1 microsecond.
20
21 The apparatus 100 may further include an inclinometer
22 (not shown) and a fluxgate compass (not shown), both of
23 which would be mounted within the casing 50. The
24 fluxgate compass generates a signal which gives a
25 bearing to the target and the inclinometer generates a
26 signal which gives the incline angle to the target.
27 These signals are preferably digitised so that they are
28 in a machine-readable form for direct manipulation by
29 the computer 120.
30
31 Thus, in addition to being used to find ranges to
32 specific targets, the survey apparatus may also be used
33 to determine the position of objects, such as
34 electricity pylons, buildings, trees or other man-made
35 or natural structures. The GPS system can be used to
36 determine the position of the apparatus 100 anywhere in

1   the world, which can be recorded. Optionally, the

2   fluxgate compass within the casing 50 measures the

3   bearing to the target, which can be used to determine

4   the position of the target using the reading from the

5   GPS system and the reading from the fluxgate compass.

6

7   It should also be noted that the encoders 62, 70 may be

8   used to determine the bearing to the target instead of

9   the fluxgate compass. In this case, if the encoder is

10   given an absolute reference, such as the bearing to an

11   electricity tower or other prominent landmark which is

12   either known or can be calculated, then the angle

13   relative to the reference bearing can be calculated

14   using the outputs from the encoders 62, 70, thus giving

15   the bearing to the target.

16

17   In addition, the position of the apparatus and the

18   calculated position of the target could be overlayed on

19   a map displayed on the computer screen so that the

20   accuracy of the map can be checked. This would also

21   allow more accurate maps to be drawn.

22

23   Referring to Fig. 14, there is shown an exemplary image

24   printed from the screen of the computer 120. The

25   survey apparatus 100 of the present invention is

26   advantageously operated remotely. As the apparatus 100

27   is computer-controlled, remote operation of the system

28   can be achieved via the Internet, a telemetry link or a

29   phone line for example. The survey apparatus 100 is

30   particularly suited to applications where surveying is

31   required in hazardous and/or hostile environments.

32

33   Thus, as show in Fig. 14, the screen image may include

34   a sighting graticule 150 which allows the user to

35   select the target with increased accuracy. The

36   orientation of the apparatus 100 can be moved using any

21

1   particular control means associated with the computer
2   such as a mouse, joystick or the like. In particular,
3   the apparatus 100 may be moved by the user clicking on
4   a particular target within the image on the screen
5   using a mouse for example. As the apparatus is moved,
6   the camera 32 will display an image on the screen which
7   the user can use to determine the target area.
8
9   Thereafter, the apparatus 100 will be activated by
10   pressing a key, clicking a mouse button or by any other
11   conventional means, and the camera 32 will take the
12   freeze frame which will be displayed on the computer
13   screen. The user can then select which target he
14   wishes to range too within the picture using the mouse
15   pointer. This will give the two-dimensional x, y pixel
16   coordinates for the selected object. The computer 120
17   may then calculate the horizontal and vertical angles
18   H_A, V_A as described above. The computer 120 then
19   instructs the motors 60, 68 to pan and tilt through
20   their respective angles until the laser transmit beam
21   22 is pointing at the object of interest. This may
22   require the iteration process described above to ensure
23   that the laser beam 22 is accurately aligned with the
24   target object. Once the beam 22 is aligned with the
25   object, the laser 12 will be activated to determine the
26   range R to a particular object. Once the range is
27   known, the screen image can be overlayed with the range
28   and the horizontal and vertical angles H_A, V_A, as
29   indicated generally by 152 in Fig. 14. This
30   information can then be saved for future reference
31   and/or analysis.
32
33   The apparatus 100 is particularly suited to
34   applications in hostile and/or hazardous environments.
35   The apparatus 100 can be operated remotely and thus
36   ensures that the user can survey an area of interest

1   from a relatively safe, remote environment.

2

3   The apparatus 100 can be mounted on top of a tripod

4   stand, mounted on a vehicle on a telescopic mast, or on

5   an elevated platform for greater visibility. The

6   apparatus 100 can be used to measure the range to most

7   types of surfaces including earth, coal, rock and

8   vegetation at distance in excess of 1 kilometre (km).

9

10 Referring to Figs 15a to c, there is shown a vehicle

11 160 (such as a tank) which is provided with the

12 apparatus 100 mounted on a telescopic or extendable arm

13 162. As illustrated in Fig. 15a, the apparatus 100 may

14 be completely retracted when the vehicle 160 is in

15 motion, and may be stored behind an armoured shield

16 164. The casing 50 of the apparatus 100 would tilt

17 downwards to a horizontal attitude and the telescopic

18 arm 162 would extend so that the apparatus 100 was

19 substantially protected by the armoured shield 164.

20

21 When the area to be surveyed is reached, the vehicle is

22 stopped and the apparatus 100 deployed on the

23 telescopic arm 162 by reversing the procedure described

24 above, as illustrated in Fig. 15b. The telescopic arm

25 is preferably mounted on a rotation joint 166 so that

26 the apparatus 100 can be rotated through 360° as

27 indicated by arrow 168 in the enlarged portion of Fig.

28 15b. A motor 170 is coupled to the rotation joint 166

29 to facilitate rotation of the joint 166. The apparatus

30 100 can typically be raised to a height of

31 approximately 15 metres or more, depending upon the

32 construction of the arm 162.

33

34 The particular configuration shown in Figs 15a and 15b

35 can accommodate large angles of roll and pitch of the

36 vehicle, such as that shown in Fig. 15c. In Fig. 15c,

1 the vehicle 160 is stationary on a slope 172 and has

2 been rolled through an angle indicated by arrow 174 in

3 Fig. 15c. The user or the computer can correct for the

4 angle of roll 174 by moving the arm 162 until the

5 inclinometer indicates that the apparatus 100 is level.

6 A level 178 (Figs 16a, 16b) may be provided on the base

7 of the apparatus 100 if required.

8

9 Figs 16a and 16b are front and side elevations of the

10 apparatus 100 mounted on the arm 162. As can be seen

11 from Figs 16a and 16b, the arm 162 can be rotated

12 through 360° as indicated by arrow 176 in Fig. 16a.

13 The apparatus 100 is mounted on a pan and tilt head 180

14 to facilitate panning and tilting of the apparatus 100.

15

16 Servo motors within the pan and tilt head 180 pan and

17 tilt the head 180 into the plane of roll and pitch of

18 the vehicle 160 (Fig. 15c). Thereafter, the motors 60,

19 68 of the apparatus 100 pan and tilt the apparatus 100

20 until it is level, using the level indicator 178 as a

21 guide.

22

23 Further electronic levels (not shown) within the

24 apparatus 100 can measure any residual dislevelement

25 and this can be corrected for in the software before

26 any measurements are taken.

27

28 A particular application of the apparatus 100 deployed

29 on a vehicle 160 would be in a military operation. The

30 apparatus 100 can be deployed remotely on the arm 162

31 and used to survey the area surrounding the vehicle

32 160. The computer 120 could be provided with a ground

33 modelling software package wherein the user selects a

34 number of key targets within the area using the method

35 described above, and finds the range and bearing to,

36 height of and global position of (if required) these

24

1   targets. The software package will then plot these
2   points, including any heights which the GPS 182 (Figs
3   16a, 16b) can generate, and in-fill or morph the
4   remaining background to produce an image of the
5   terrain, such as that shown in Fig. 17.
6
7   Fig. 17 shows an exemplary terrain which has been
8   surveyed, the terrain including a river 190, the river
9   190 being in a valley with sides 192, 194 raising
10   upwardly from the river 190. Once the ground has been
11   modelled, design templates of equipment carried by the
12   vehicle 160 (or any other vehicle, aircraft etc) can be
13   overlayed over the image to assess which type of
14   equipment is required to cross the obstacle, such as
15   the river 190. The surveying operation can be done
16   discretely and in a very short time compared with
17   conventional survey techniques. Such conventional
18   techniques would typically be to deploy a number of
19   soldiers to survey the area manually and report back.
20   However, with the apparatus 100 deployed on the vehicle
21   160 the survey can be done quicker, more accurately and
22   more safely, without substantial risk to human life.
23
24   It is possible to conduct multiple surveys with the
25   vehicle 160 in one or more locations, with the data
26   from each survey being integrated to give a more
27   accurate overall survey of the surrounding area.
28
29   Furthermore, if the arm 162 was disposed at the front
30   of the vehicle 160 as shown in Figs 18a and 18b, the
31   apparatus 100 can be used to check the profile of the
32   ground in front of the vehicle 160. Thus, the profile
33   of the ground could be shown in profile and plan views
34   as illustrated in Figs 19a, and 19b respectively.
35   Alternatively, or additionally, the software on the
36   computer 120 could be used to generate a head-up video

1   display to which the driver of the vehicle 160 could

2   refer. Fig. 20 illustrates an example of the type of

3   head-up display which could be generated. The heading

4   of the tank (measured by the fluxgate compass) is

5   displayed, with the range to and height of the ground

6   (and any obstructions) in front of the vehicle also

7   being displayed. The height displayed could be the

8   height relative to the vehicles' position, or could be

9   the absolute height obtained from the GPS 182.

10

11   Figs 21 to 23 illustrate three further applications of

12   the apparatus 100. Fig. 21 illustrates how to

13   calculate the height between two points A and B

14   (indicated by crosses in Fig. 21). The user will

15   select the points A and B and then measure the range to

16   them using the method described above. This will give

17   three-dimensional coordinates for each point A and B.

18   If it is assumed that the range to each point is

19   approximately equal (which can be checked using the

20   measured ranges) and that the x co-ordinates for each

21   point are approximately equal (this can be done using

22   the display of x, y and z co-ordinates displayed on the

23   screen), then the height from A to B is given by

24   subtracting their respective y coordinates. This can

25   then be displayed within a separate window within the

26   screen, for example.

27

28   Fig. 22 illustrates the technique used to measure the

29   height and distance between two points A and B. The

30   range to A and B are first measured using the apparatus

31   100 as described above. The slope from A to B, the

32   horizontal difference between A and B and the gradient

33   of A to B are then calculated, the results being

34   overlayed on the screen.

35

36   Fig. 23 illustrates how a rock face or the like may be

26

1   profiled. Range measurements are taken at intervals
2   along the profile (indicated by crosses in Fig. 23).
3   The height of each measurement will be calculated from
4   either the inclinometer reading or can be determined
5   using the GPS 182. Thus, a rock profile may be
6   produced, as shown in Fig. 23.
7
8   While the above is a description of the typical
9   applications which the survey apparatus of the present
10   invention may be used for, it will be apparent to those
11   skilled in the art the full range of applications of
12   the survey apparatus disclosed herein, and the present
13   invention is not limited to the examples discussed.
14
15   Thus, there is provided a survey apparatus and method
16   which provides for remote control operation using a
17   video camera to relay images back to a host computer in
18   real-time. The image on the host computer allows the
19   user to select particular objects of interest within
20   the surveyed area and measure the range to these
21   objects. The apparatus can also be used to determine
22   rock profiles, heights between two points, the position
23   of certain objects and the like.
24
25   Modifications and improvements may be made to the
26   foregoing without departing from the scope of the
27   present invention.
28

27

1   **CLAIMS**

2

3   1.   A survey apparatus comprising a range finder, a

4   camera and a processor capable of processing image and

5   range signals, wherein the camera facilitates aiming of

6   the range finder.

7

8   2.   A survey apparatus according to claim 1, wherein

9   the camera comprises a video camera.

10

11   3.   A survey apparatus according to either preceding

12   claim, wherein the camera comprises a digital camera.

13

14   4.   A survey apparatus according to any preceding

15   claim, wherein the apparatus includes a display device

16   to allow a user of the apparatus to view a target area

17   using the camera.

18

19   5.   A survey apparatus according to claim 4, wherein

20   the display device comprises a VGA monitor.

21

22   6.   A survey apparatus according to any preceding

23   claim, wherein the processor comprises a computer.

24

25   7.   A survey apparatus according to any preceding

26   claim, wherein the range finder comprises a laser range

27   finder.

28

29   8.   A survey apparatus according to any preceding

30   claim, wherein the range finder is bore-sighted with

31   the camera.

32

33   9.   A survey apparatus according to any preceding

34   claim, wherein the apparatus includes a pan and tilt

35   unit for panning and tilting of the range finder and/or

36   camera.

28

1   10.   A survey apparatus according to claim 9, wherein
2   the pan and tilt unit comprises a first motor for
3   panning of the range finder and/or camera, and a second
4   motor for tilting of the range finder and/or camera.
5
6   11.   A survey apparatus according to either claim 9 or
7   claim 10, wherein operation of the first and second
8   motors is controlled by the processor.
9
10 12.   A survey apparatus according to any one of claims
11 9 to 11, wherein the pan and tilt unit includes first
12 and second digital encoders for measuring the angles of
13 pan and tilt.
14
15 13.   A survey apparatus according to claim 12, wherein
16 the outputs of the first and second encoders are fed to
17 the processor.
18
19 14.   A survey apparatus according to claim 13, wherein
20 a feedback loop is provided wherein the motors are
21 capable of being operated to pan and tilt the range
22 finder and/or camera through the generated horizontal
23 and vertical angles, and the encoders are capable of
24 verifying the angles moved to verify that the range
25 finder and/or camera were panned and tilted through the
26 correct angles.
27
28 15.   A survey apparatus according to any one of claims
29 12 to 14, wherein the first and second encoders are
30 used to calculate the bearing to the target.
31
32 16.   A survey apparatus according to according to any
33 preceding claim, wherein the image is digitised.
34
35 17.   A survey apparatus according to claim 16, wherein
36 the image comprises a plurality of pixels.

18. A survey apparatus according to claim 17, wherein the reference point comprises a pixel within the target area.

19. A survey apparatus according to any preceding claim, wherein the reference point comprises a centre point of the target area.

20. A survey apparatus according to any one of claims 16 to 19, wherein the target is selected by selecting a pixel within the target.

21. A survey apparatus according to any preceding claim, wherein the survey apparatus includes a compass and an inclinometer and/or gyroscope.

22. A survey apparatus according to claim 21, wherein the compass comprises a digital fluxgate compass.

23. A survey apparatus according to either claim 21 or claim 22, wherein signals from the compass, inclinometer and/or gyroscope are processed to provide data to the processor.

24. A survey apparatus according to any preceding claim, wherein the survey apparatus further includes a position fixing system for identifying the geographical position of the apparatus.

25. A survey apparatus according to claim 24, wherein the position fixing system comprises a Global Positioning System.

26. A survey apparatus according to claim 25, wherein the Global Positioning System includes a Differential Global Positioning System.

1   27.   A survey apparatus according to either one of
2   claims 24 to 26, wherein the signal from the position
3   fixing system is processed to provide data to the
4   processor.
5
6   28.   A survey apparatus according to any preceding
7   claim, wherein the survey apparatus is mounted on a
8   mounting device.
9
10   29.   A survey apparatus according to claim 28, wherein
11   the mounting device comprises a tripod stand.
12
13   30.   A survey apparatus according to any preceding
14   claim, wherein the apparatus can is mounted on an
15   elevating platform, telescopic elevating tube,
16   telescopic arm or robotic arm.
17
18   31.   A survey apparatus according to claim 30, wherein
19   the elevating platform, telescopic elevating tube,
20   telescopic arm or robotic arm is capable of 360°
21   rotation.
22
23   32.   A survey apparatus according to either claim 29 or
24   claim 30, wherein the elevating platform, telescopic
25   elevating tube, telescopic arm or robotic arm is
26   mounted on a vehicle.
27
28   33.   A survey apparatus according to claim 32, wherein
29   the apparatus allows data gathering from within the
30   vehicle to construct a digital terrain model of the
31   terrain surrounding the vehicle.
32
33   34.   A method of measuring the range to a target, the
34   method comprising the steps of
35   providing a camera to view a target area;
36   providing a range finder;

31

1   using the camera to produce an image of the target

2   area;

3   selecting the target within the target area;

4   generating horizontal and vertical angles between

5   a reference point and the target; and

6   moving the range finder and/or camera, if

7   required, through the generated horizontal and vertical

8   angles to measure the range to the target.

9

10   35.   A method according to claim 34, wherein the camera

11   comprises a video camera.

12

13   36.   A method according to either claim 34 or claim 35,

14   wherein the camera comprises a digital camera.

15

16   37.   A method according to any preceding claim, wherein

17   the apparatus includes a display device to allow a user

18   of the apparatus to view a target area using the

19   camera.

20

21   38.   A method according to claim 37, wherein the

22   display device comprises a VGA monitor.

23

24   39.   A method according to any one of claims 34 to 38,

25   wherein the processor comprises a computer.

26

27   40.   A method according to any one of claims 34 to 39,

28   wherein the range finder comprises a laser range

29   finder.

30

31   41.   A method according to any one of claims 34 to 40,

32   wherein the range finder is bore-sighted with the

33   camera.

34

35   42.   A method according to any one of claims 34 to 41,

36   wherein the image is digitised.

1   43.   A method according to claim 42, wherein the image

2   comprises a plurality of pixels.

3

4   44.   A method according to claim 43, wherein the

5   reference point comprises a pixel within the target

6   area.

7

8   45.   A method according to any one of claims 34 to 43,

9   wherein the reference point comprises a centre point of

10 the target area.

11

12 46.   A method according to any one of claims 42 to 45,

13 wherein the target is selected by selecting a pixel

14 within the target.

15

16 47.   A method according to claim 46, wherein the target

17 pixel is selected using a mouse pointer.

18

19 48.   A method according to any one of claims 34 to 47,

20 wherein the method comprises the further steps of

21   obtaining a focal length of the camera;

22   obtaining a field of view of the camera;

23   calculating the principal distance of the camera;

24   obtaining the horizontal offset and vertical

25 offset between an axis of the camera and an axis of the

26 laser;

27   calculating the horizontal and vertical offsets in

28 terms of pixels;

29   calculating the difference between the horizontal

30 and vertical offsets in terms of pixel and the x and y

31 coordinates of the target pixel; and

32   calculating the horizontal and vertical angles.

33

34 49.   A method according to any one of claims 34 to 48,

35 wherein the apparatus includes a pan and tilt unit for

36 panning and tilting of the range finder and/or camera.

33

50.   A method according to claim 49, wherein the pan
and tilt unit comprises a first motor for panning of
the range finder and/or camera, and a second motor for
tilting of the range finder and/or camera.

51.   A method according to either claim 49 or claim 50,
wherein operation of the first and second motors is
controlled by the processor.

52.   A method according to any one of claims 49 to 51,
wherein the pan and tilt unit includes first and second
digital encoders for measuring the angles of pan and
tilt.

53.   A method according to claim 52, wherein the
outputs of the first and second encoders is fed to the
processor.

54.   A method according to claim 53, wherein a feedback
loop is provided wherein the motors are operated to pan
and tilt the range finder and/or camera through the
generated horizontal and vertical angles, and the
encoders are used to check the angles to ensure that
the range finder and/or camera were panned and tilted
through the correct angles.

55.   A method according to any one of claims 48 to 54,
the method comprising the further steps of
      instructing the pan and tilt unit to pan and tilt
the range finder and/or camera through the vertical and
horizontal angles;
      measuring the horizontal and vertical angles using
the encoders;
      verifying that the angles through which the range
finder and/or camera are moved is correct;

1   obtaining horizontal and/or vertical correction

2 angles by subtracting the measured horizontal and

3 vertical angles from the calculated horizontal and

4 vertical angles;

5   adjusting the pan and tilt of the range finder

6 and/or camera if necessary; and

7   firing the range finder to obtain the range to the

8 target.

9

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

4 / 11

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10
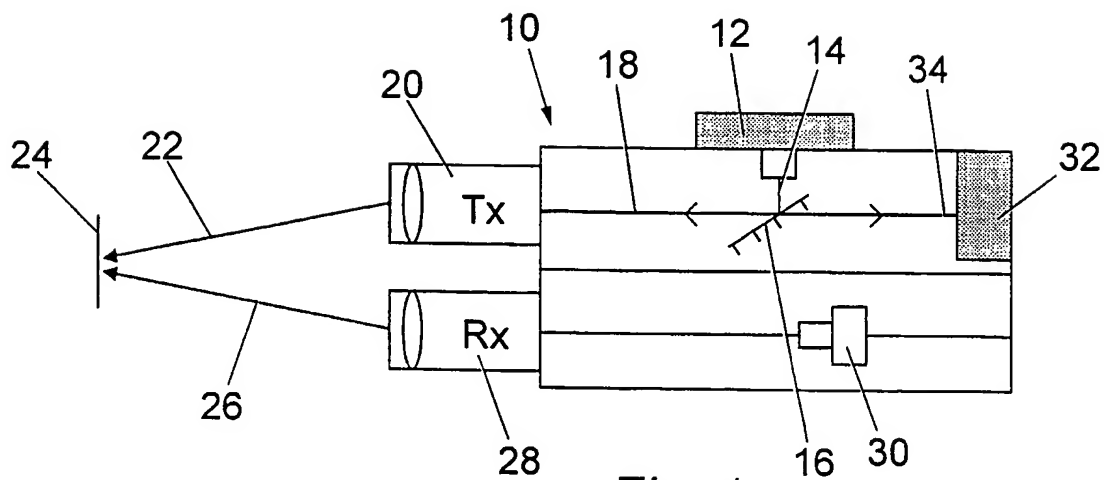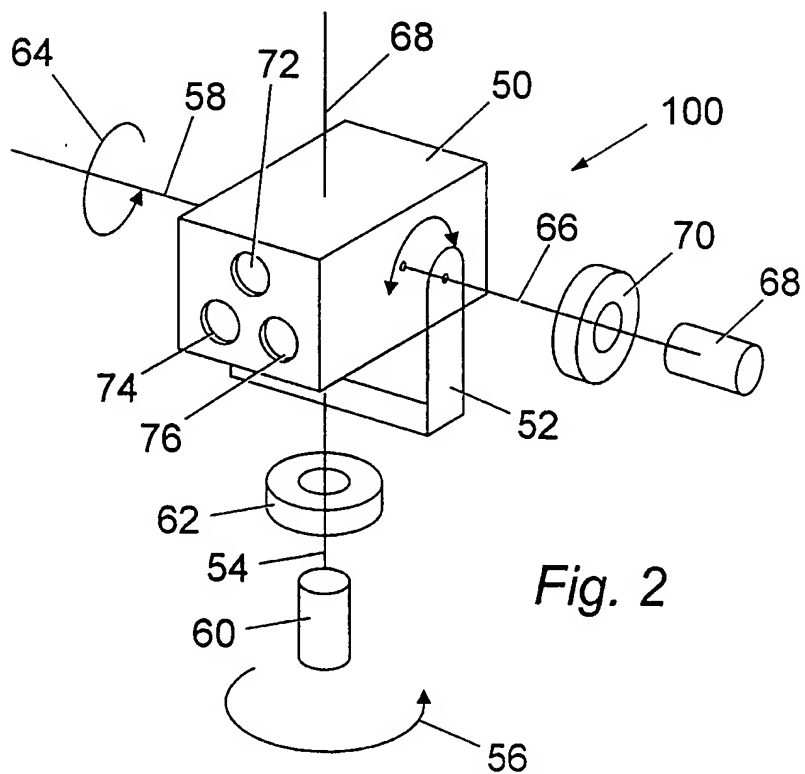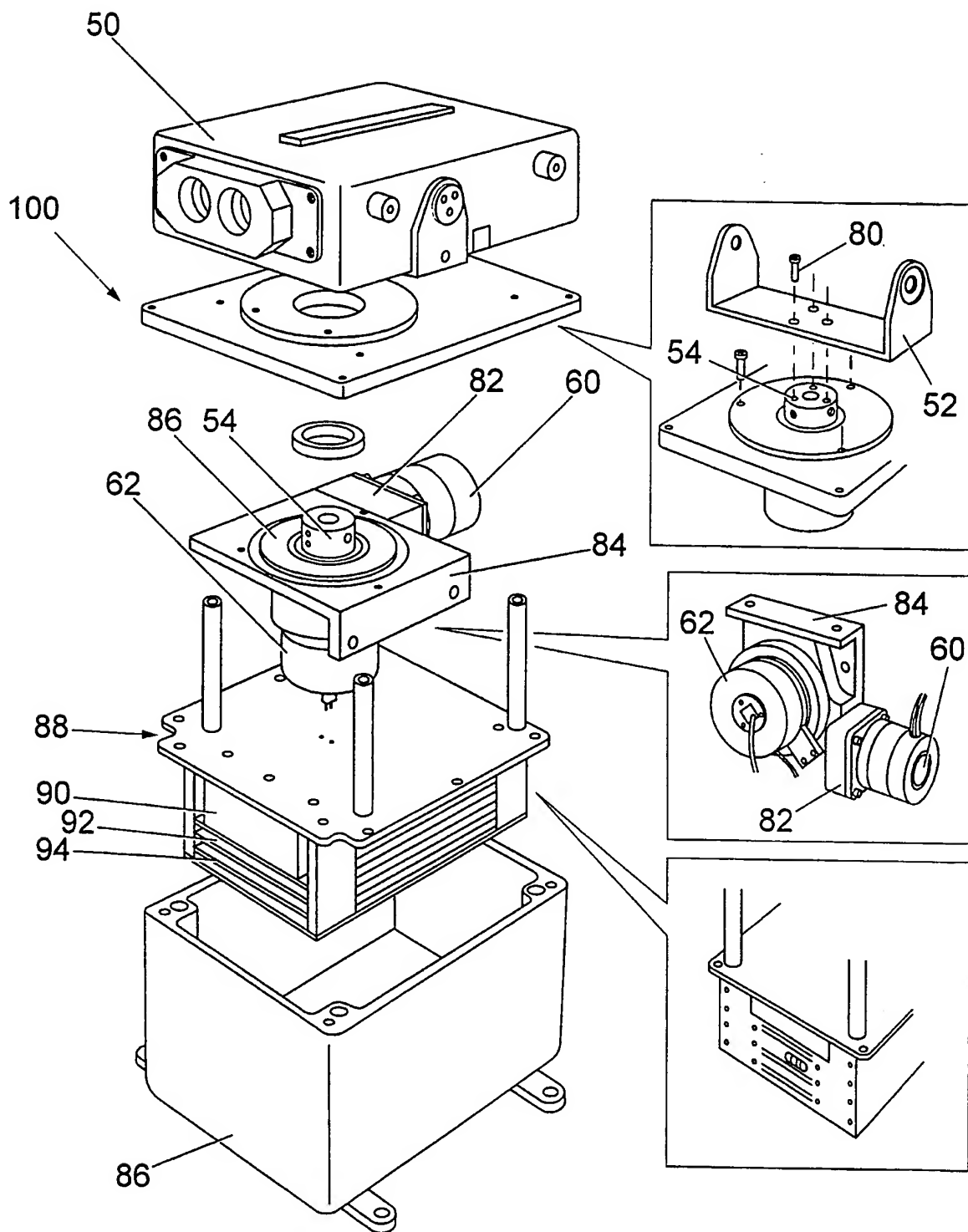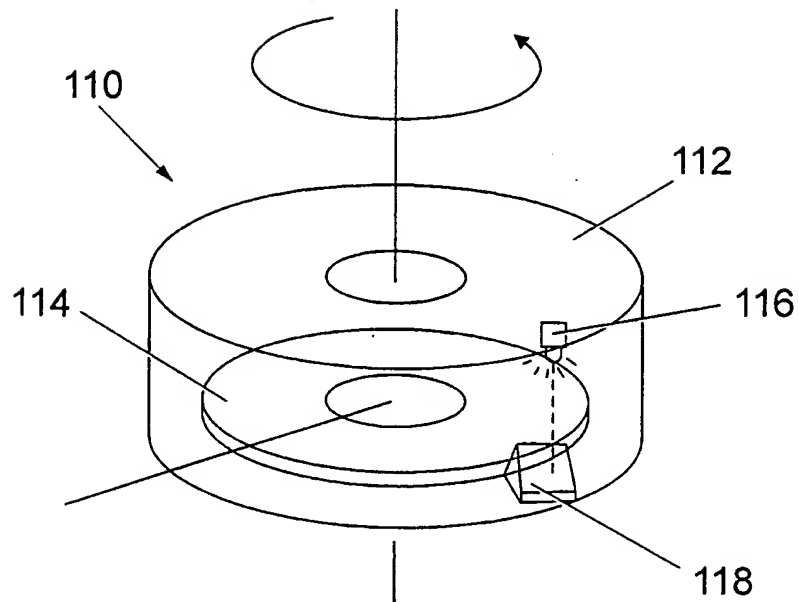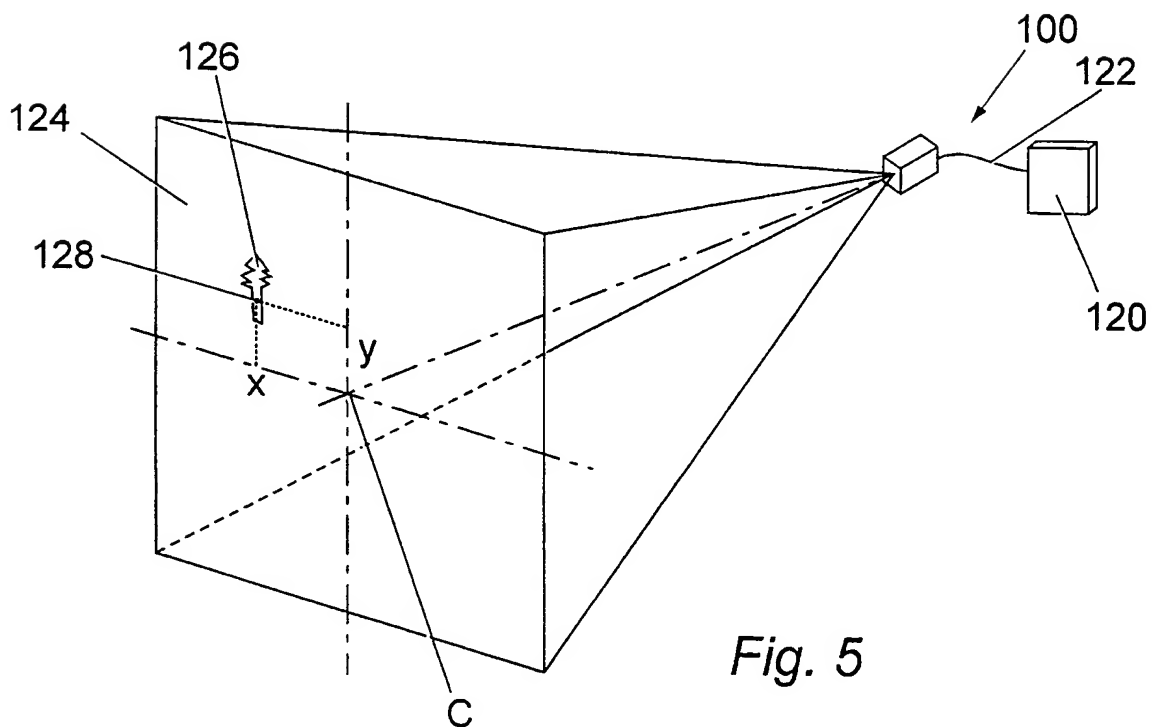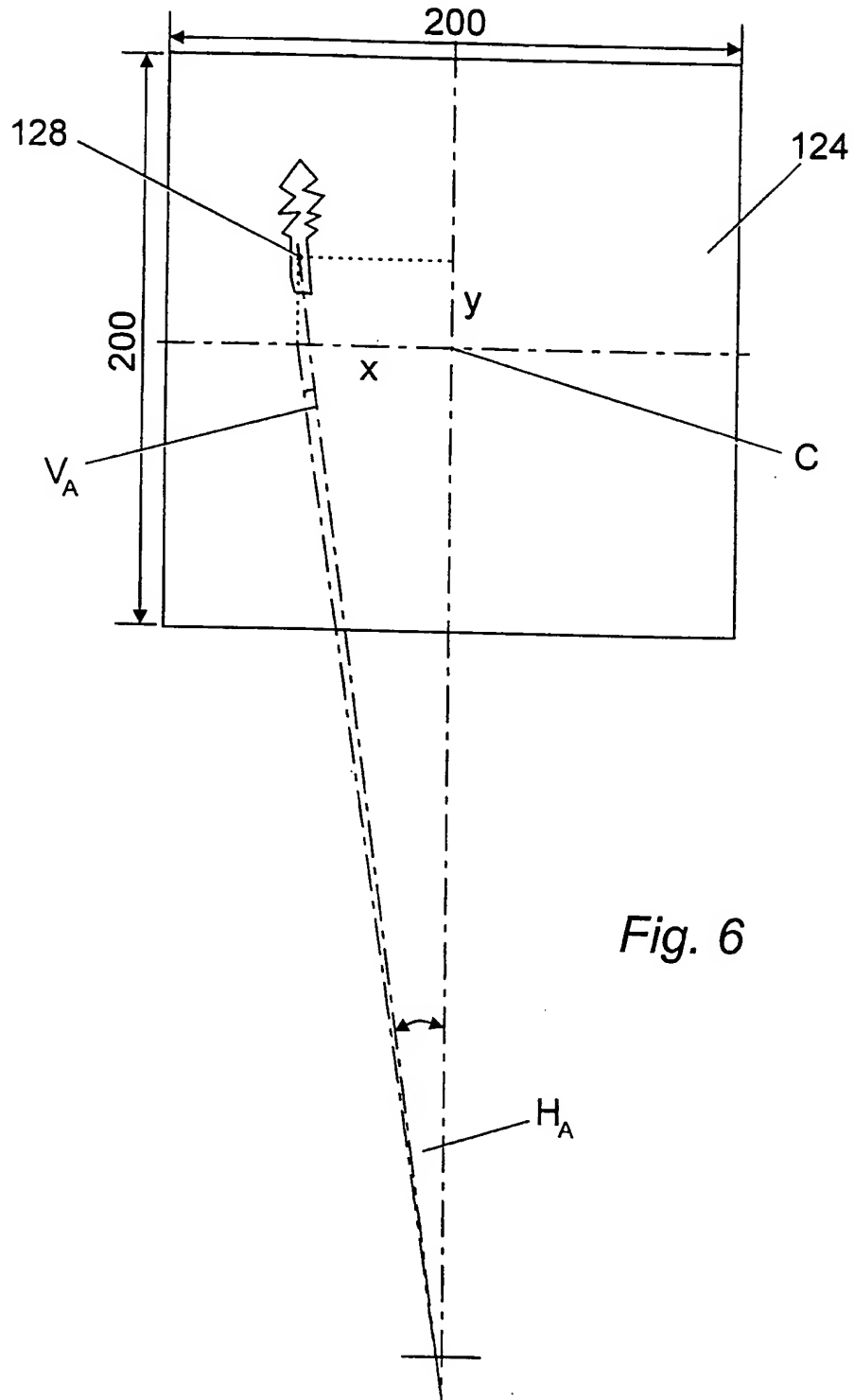
Fig. 11
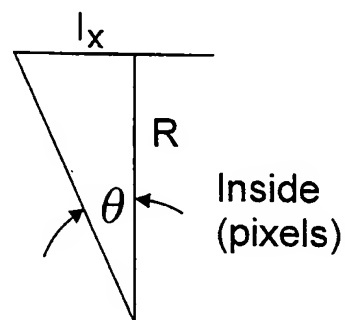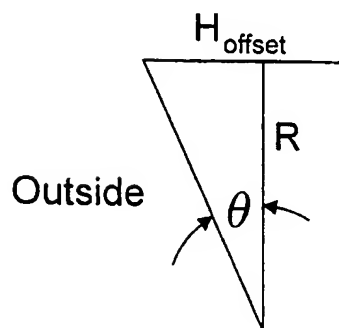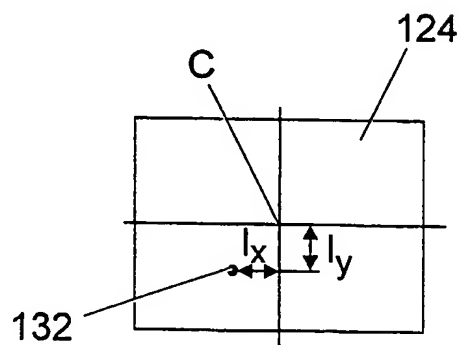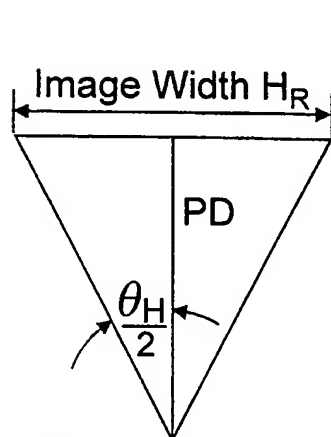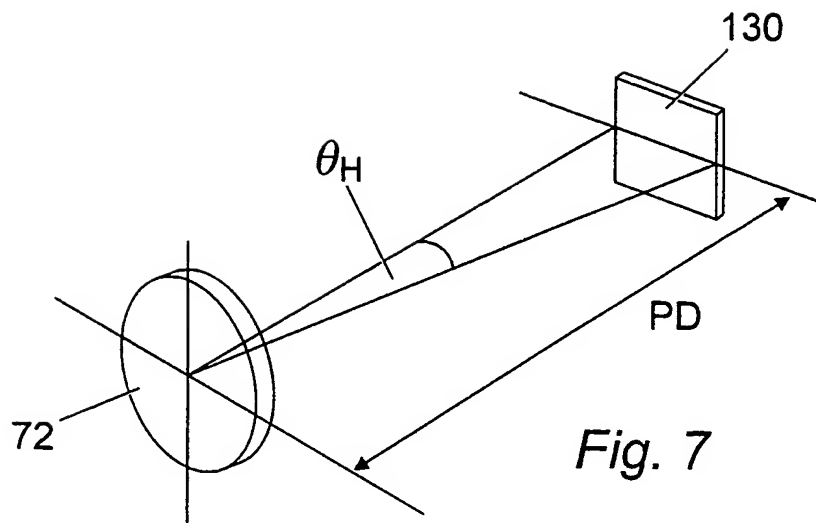
6 / 11
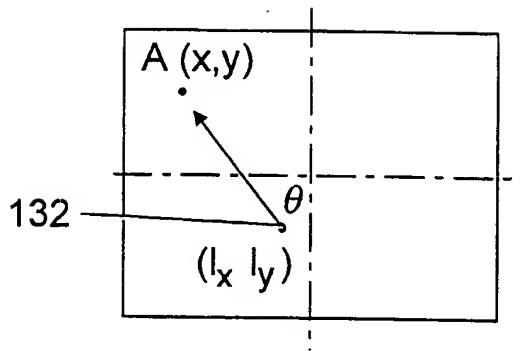
Fig. 12

Fig. 13

Fig. 14

7 / 11

Fig. 15a

Fig. 15b

Fig. 15c

Fig. 16a

Fig. 16b

Fig. 17

Fig. 18a

Fig. 18b

HEIGHT RELATIVE TO ORIGINAL TRACTOR POSITION
OR ABSOLUTE HEIGHT REF TO DGPS

X-SECTION

Fig. 19a

PLAN

Fig. 19b

VIDEO VIEW
GRAPHICS OVERLAY ON VIDEO CORRECTED FOR
PROJECTED TANK / CAMERA-HEADING
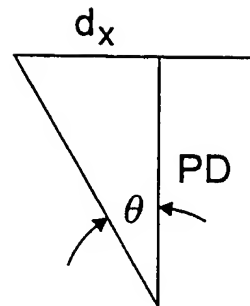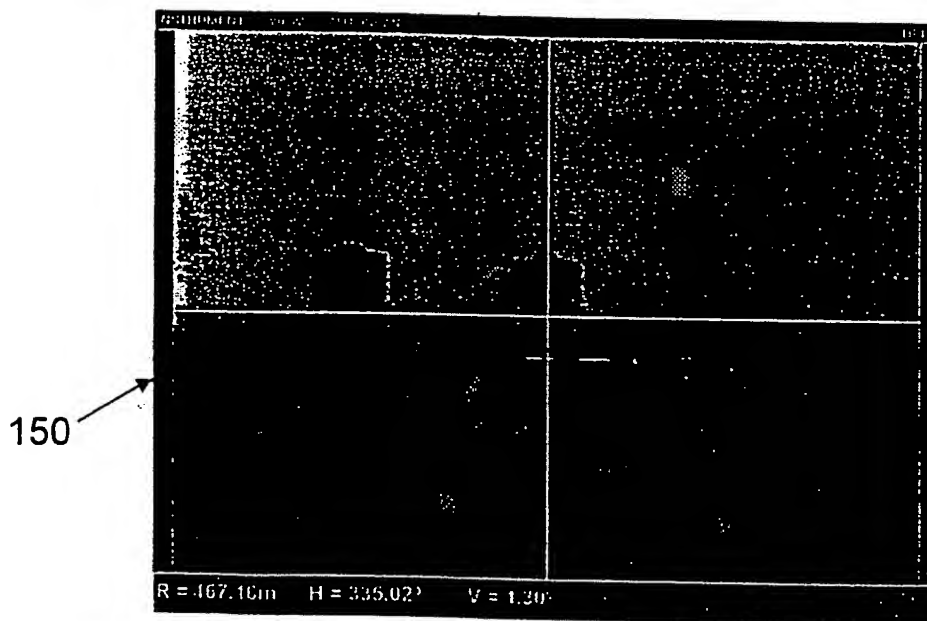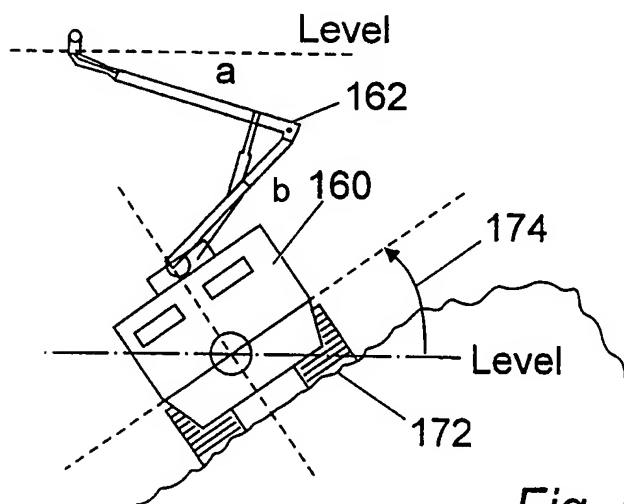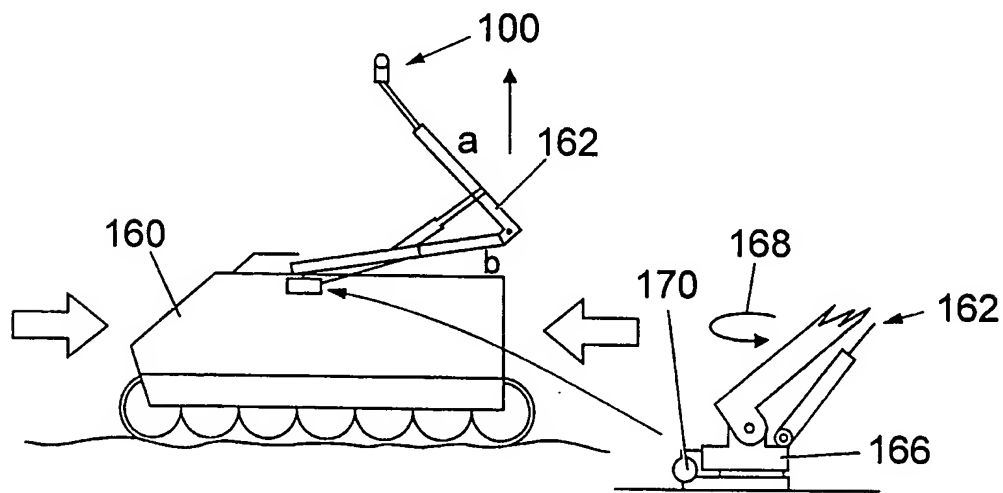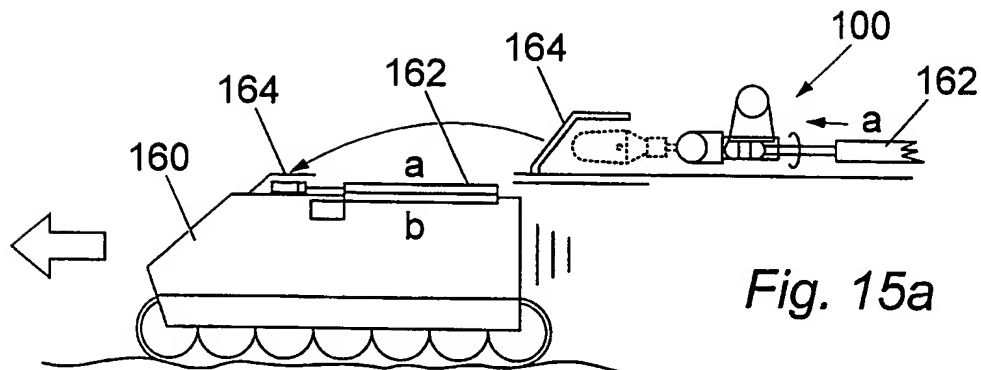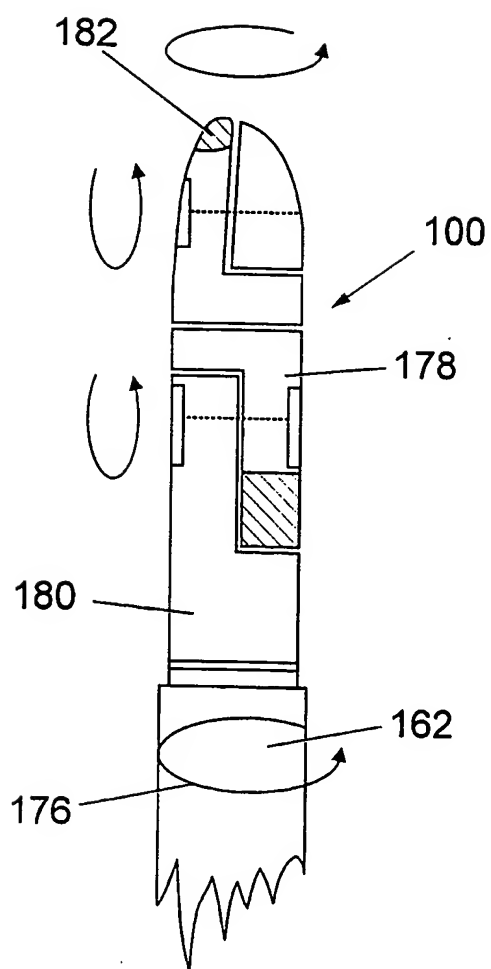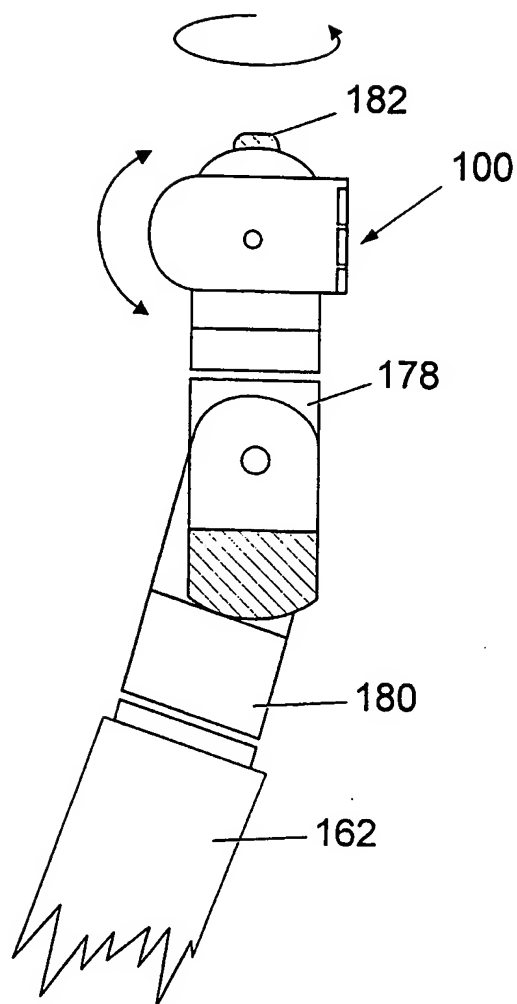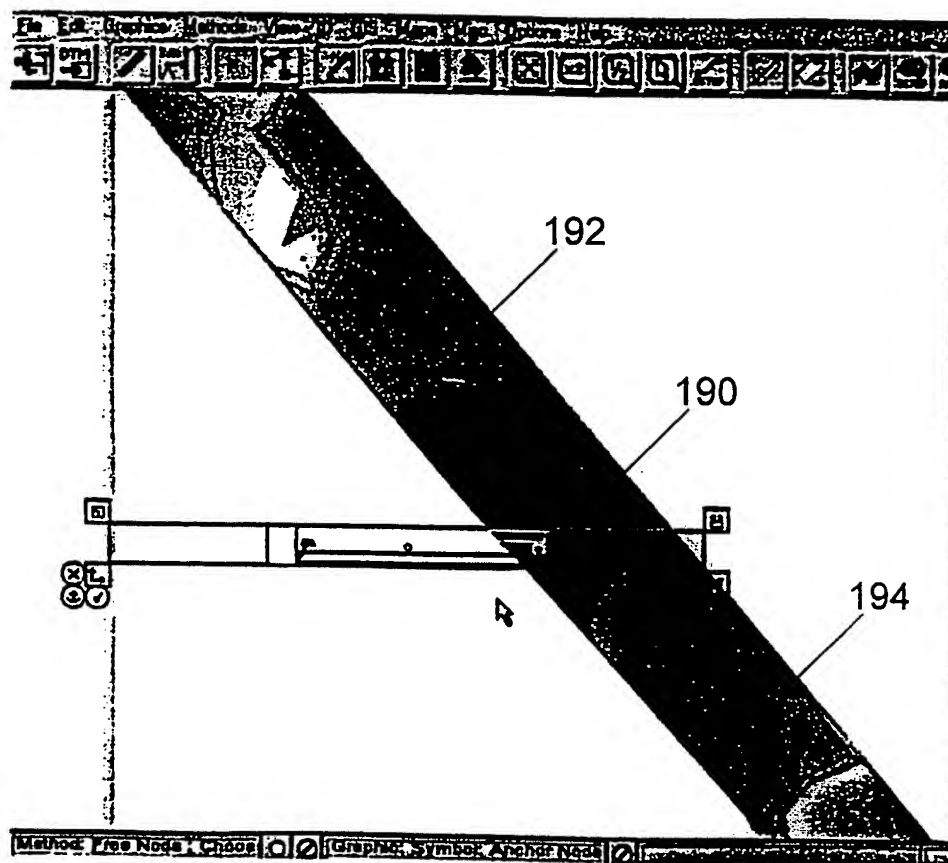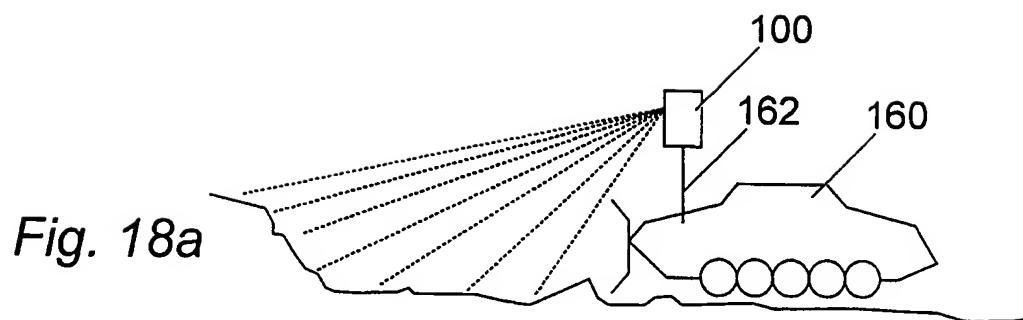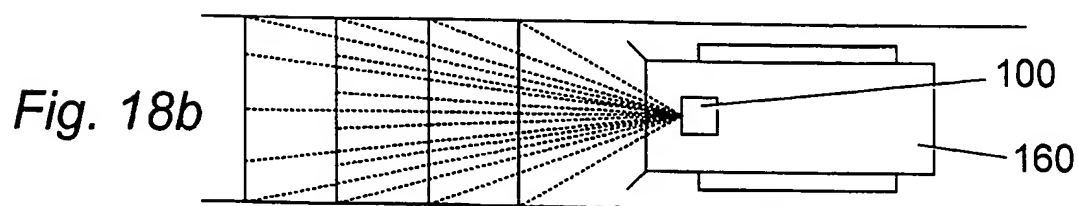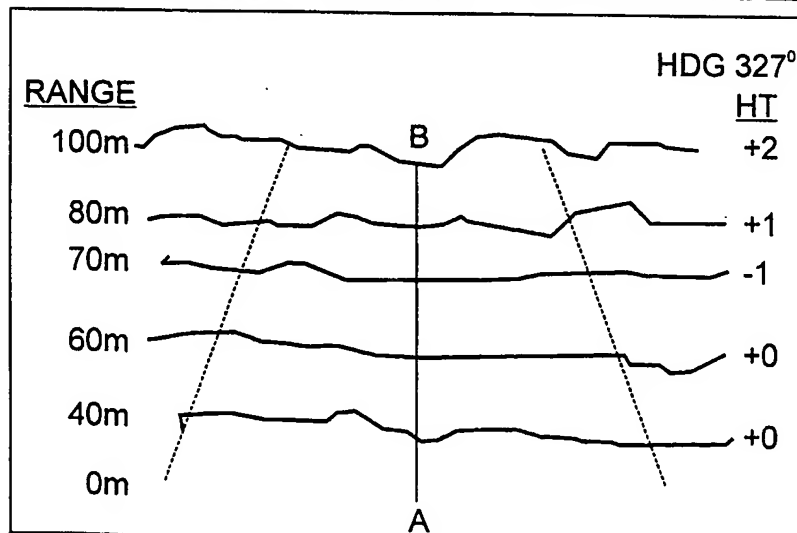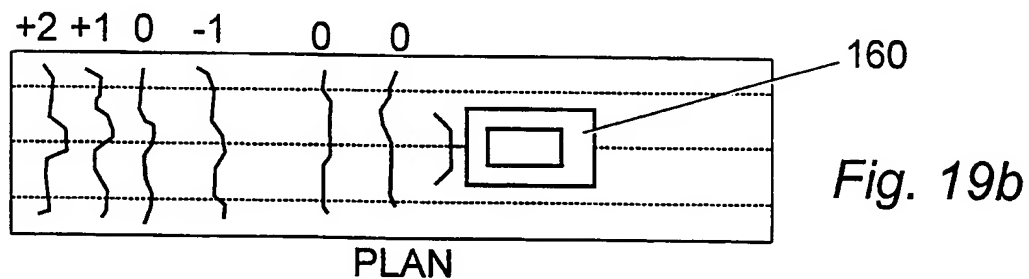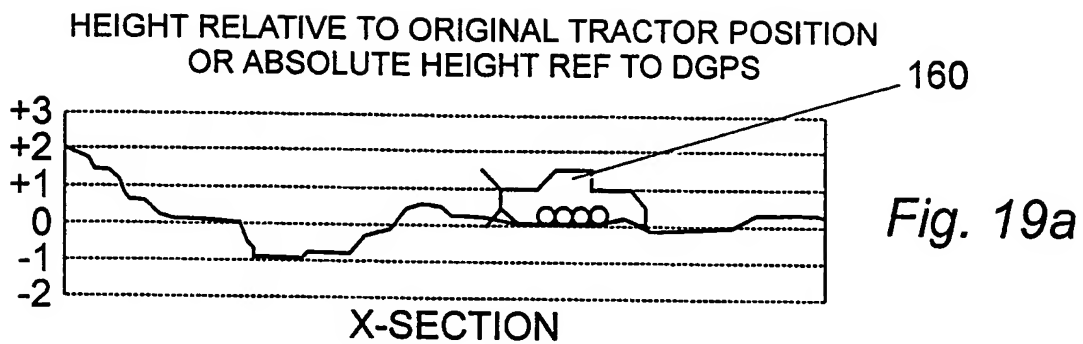
Fig. 20
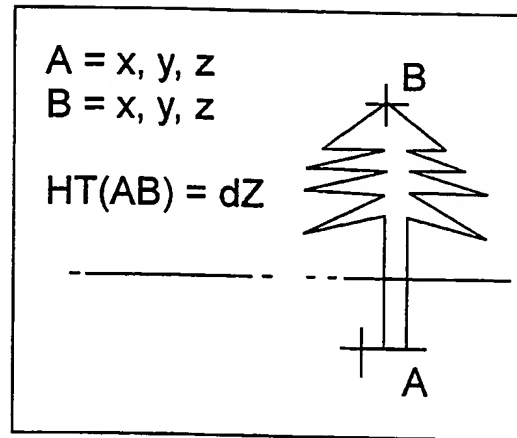
Fig. 21
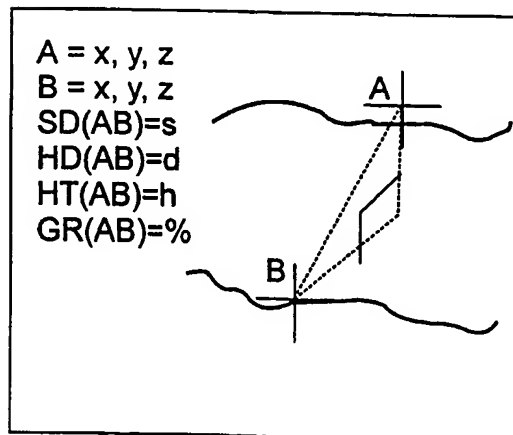
Fig. 22

Fig. 23

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6   G01C15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6   G01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 481 278 A (PIETZSCH IBP GMBH) 22 April 1992 (1992-04-22)	1,4-7, 9-14,34, 37-40, 49-54
Y	column 4, line 17 - line 23	21, 23-25, 27,28, 30,32,33
	column 5, line 28 - column 7, line 11; figures	

Y	US 5 077 557 A (INGENSAND HILMAR) 31 December 1991 (1991-12-31)	21, 23-25, 27,28
	column 2, line 4 - line 17; figures	

	-/--	

| [X] | Further documents are listed in the continuation of box C. | [X] | Patent family members are listed in annex. |

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 August 1999	26/08/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hoekstra, F

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INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 379 045 A (GILBERT CHARLES ET AL) 3 January 1995 (1995-01-03) column 9, line 51 - column 10, line 4 column 13, line 1 - line 6; figures 1,2 ---	30,32,33
X	EP 0 661 519 A (TOPCON CORP) 5 July 1995 (1995-07-05) the whole document -----	1,3-6, 8-13, 34-39, 41,45, 49-53

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INTERNATIONAL SEARCH REPORT

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			DE	9007731 U	10-11-1994
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